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Discovery of a new 2.3 s isomer in the neutron-rich nucleus ^{174}Tm

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Abstract. A new program of K-isomer research has been initiated with the 8π detection system sited at the ISAC facility of TRIUMF. We discuss in this paper the identification of a new 2.3 s isomer in ^{174}Tm and its implications

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1 Introduction, Experiment and Results

The detection of K-isomers is an active area of current nuclear structure research. In particular, one of the goals of a future study involving neutron-rich nuclei in the Lu-Hf region is to search for the possible existence of an 'island' of β-decaying high-K isomers [1]. The close proximity of high-K states to the Fermi surface in the neutron-rich A=170-190 nuclei makes this region very attractive to search for high-K isomers [1,2]. In the present work, nuclei far from stability are produced at the ISAC facility sited at TRIUMF, Canada using 500 MeV proton-induced reactions on Ta targets, extracted using a surface ionization source, and accelerated to an energy of 30 keV. A high resolution mass analyzer separates species with different mass number, which are then transported to the experimental stations such as the 8π spectrometer. This spectrometer is an array of 20 Compton-suppressed high-purity germanium detectors [3] which is used to detect γ-rays from the implanted nuclei. The detection system has been augmented with a moving tape transport facility, to reduce the contaminating activity present in an isobaric beam.

In two sets of experiments several of the known K-isomers in the Lu-Hf region, with half-lives ranging from a few ms to several minutes could be accessed. We report here the discovery of a new isomer in the neutron-rich nucleus ^{174}Tm. The A=174 isobaric beam was implanted onto the moving tape transport facility, with beam-on/beam-off cycling times of 2s/2s, 3s/3s ('short'), 10s/10s and 100s/50s. The accumulated γ-ray data were dominated by the ground-state β-decay of ^{174}Tm (half-life of 5.4 m). In addition, the two known coincident γ-rays with energies of 100.3 and 152.1 keV were observed (fig. 1). These two γ-ray transitions are known to be present in the ground-state β-decay of ^{174}Er, which has a half life of 3.3 m [4]. In the present experiment we found no evidence for the production of ^{174}Er. This important argument is based on the non-observation of other strong γ-ray transitions

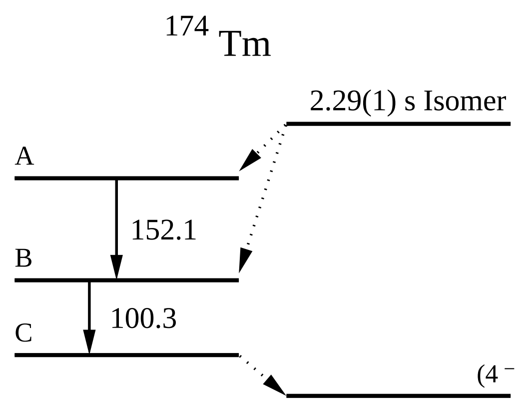

Fig. 1. Partial level scheme of ^{174}Tm. Dotted transitions have not been observed in the present experiment.

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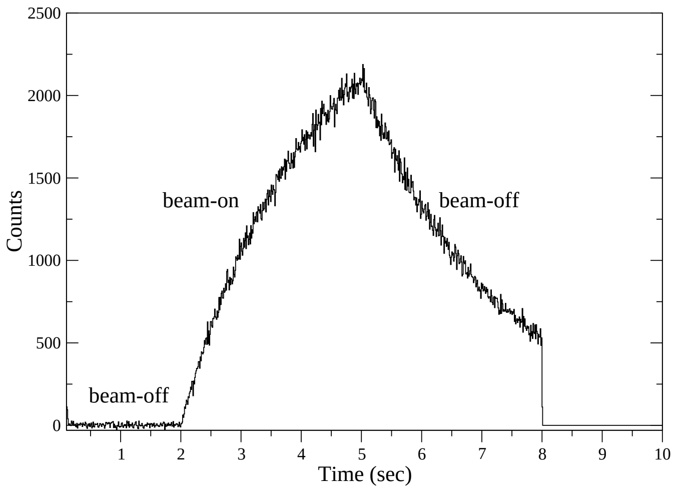

Fig. 2. Time spectrum gated by the 100.3 keV γ-ray transition. The beam-off/beam-on/beam-off tape-cycling times correspond to 2s-3s-3s.

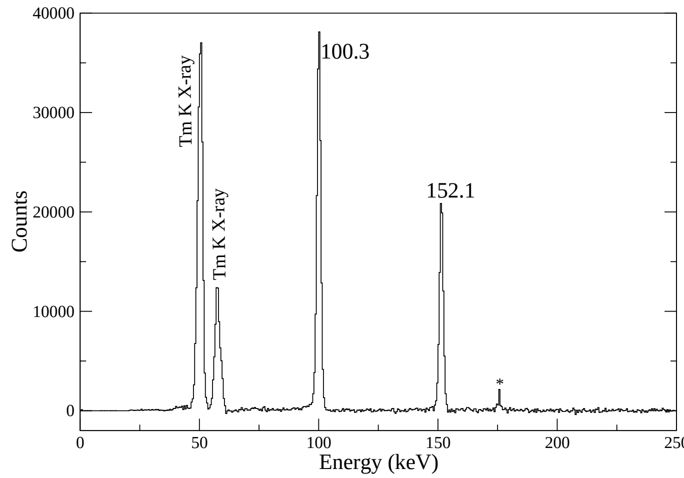

Fig. 3. Singles spectrum in the 'short'-cycling time of 2s-3s-3s corresponding to the beam-off/beam-on/beam-off periods. The dominant component due to the longer lived ^{174}Tm β-decay ($T_{1/2}$=5.4 min) has been subtracted-out. The peak marked by the asterisk symbol is a remnant of the subtraction procedure.

from the β-decay of ^{174}Er [4]. Interestingly, in the present experiment, from the γ-time matrices a new half life of 2.29(1) s could be deduced when gated by the 100 and 152 keV γ-ray transitions (fig. 2). A 'short' time-gated singles spectrum, obtained by subtracting out the long-lived β-decays, shows prominently only the Tm K X-rays and the 100 and 152 keV γ-ray transitions (fig. 3). Based on the new half-life, the singles and the coincidence data, and the absence of ^{174}Er, it is established unambigously that the origin of the 2.3 s half-life is an isomer in ^{174}Tm. From the coincidence data the K-conversion coefficients for the 100 and 152 keV γ-ray transitions were deduced to be 3.1(1) and 1.13(6) respectively, suggesting mainly M1 multipolarity. The new data are in close agreement with the theoretically expected values of 2.69 and 0.82 for M1 multipolarity, respectively, but differ from the earlier measurements [4]. A careful analysis of the 'singles' spectrum (fig. 3) has not yielded any new γ-ray transitions. The main motivation of this exercise was to locate the candidate linking γ-ray transitions between the isomer and the known excited states (labelled in fig.1 as 'A', 'B','C'), as well as between the excited states and the ground state. The new data suggest the possibility for the existence of very low-energy and highly converted transitions in the decay of the isomer and the excited states. It is to be noted that we prefer to identify the *isomeric level as a new excited state* in this nucleus as opposed to the excited state 'A' itself being isomeric. This is based on, a) a large intensity difference between the two observed γ-ray transitions, indicating direct feeding of the excited state 'B' by a cascade of low energy γ-ray transitions and/or highly converted transitions, and b), anomalously large hindrance factors if the level 'A' itself were to be the isomeric state. Another interesting facet of the isomer decay is the spins of the levels populated from the decay of the isomer. If the origin of isomerism is presumed to be at least partly due to K-hindrance, in line with several known examples in this mass region, then this level could possibly have a high K value. Based on the systematics and Nilsson model calculations of the single-particle levels in ^{174}Tm [4], the isomer is tentatively suggested to be based on a K^π=$(8^-)\pi 7/2^-[523] \otimes \nu 9/2^+[624]$ Nilsson configuration, and the other excited states ('B' and/or 'C') may be based on K^π=$((4/5)^+)\pi 1/2^+[411] \otimes \nu 9/2^+[624]$ Nilsson configurations. Thus the levels involved in the isomer decay may have spins greater than the low values suggested from the previous works [4]. The present interpretation would be consistent with the earlier data, only if the decay through the 100 and 152 keV transitions originates from a high-spin β-decaying isomer in ^{174}Er instead of the ground-state β-decay of ^{174}Er. In addition, the absence of ^{174}Yb X-rays/γ-ray transitions in the 'short' time-gated singles spectrum (fig. 3) rules out significant β-decay of the 2.3 s isomer in ^{174}Tm.

2 Summary

A new isomeric state with a half-life of 2.29(1) s has been identified in the neutron-rich odd-odd nucleus ^{174}Tm. If the isomer originates due to K hindrance, then the levels populated in the decay have spins higher than the ones deduced by the earlier ^{174}Er β-decay studies, and could possibly imply the existence of a high-spin β-decaying isomer in ^{174}Er.

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